Radon Mitigation for the CUORE Installation

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on behalf of *The CUORE Collaboration*

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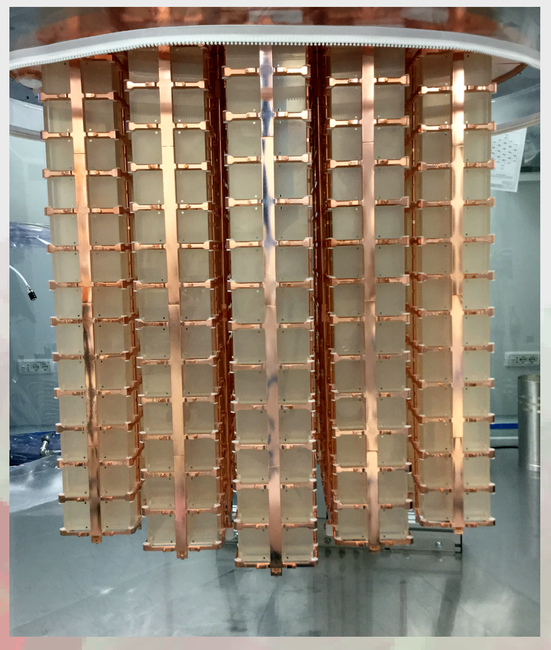
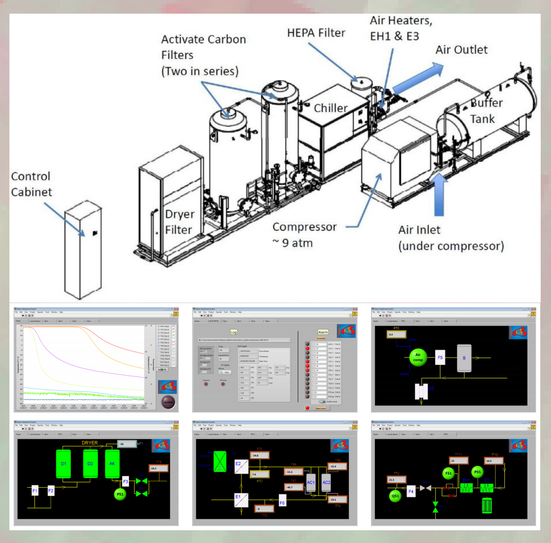
CUORE Tower Installation

- The 19 CUORE towers were successfully installed between July 27th and August 26th, 2016. The cryostat is being closed by the end of October 2016.
- In order not to induce the deposition of radioactive contaminants onto the crystals and the surrounding materials, very strong requirements were set for the entire installation period. In particular, a radon level <1 Bq/m^3 was needed.
- The installation was performed in a clean room (CR6) flushed with radon-free air. CR6 was designed, built and maintained by the LBL CUORE group. The Radon Abatement System was purchased, maintained and operated by the LBL and UC Berkeley CUORE groups.



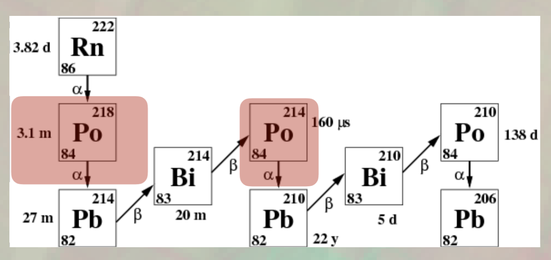
The Radon Abatement System

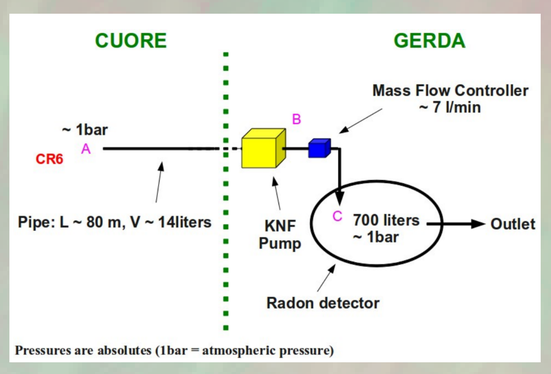
- A radon abatement system capable of delivering air with a flow rate of $\sim$150 m^3/hr and a radon content of $\sim$5 mBq/m^3 was installed in CUORE in XXXX. The main components of the system are a compressor delivering air at 8 bar to a dryer, which lowers the ambient air dew-point to $\lesssim$70°C, and hence to a chiller, where the air is cooled to -50°C. At this point two activated carbon filters in series adsorb the radon. The outgoing air is then heated to ambient temperature and the eventual carbon particles stopped by two HEPA filters.
- A LabVIEW VI was developed for monitoring the radon abatement system remotely and for sending alarms to the CUORE Alarm Server in case of misbehaviors.
- The radon abatement system was connected to a 100 KVA UPS capable of maintaining the system running for $\sim$35 minutes.

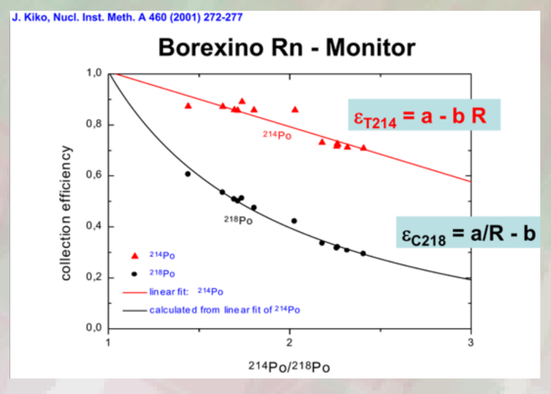


The Radon Monitor

- The radon level in CR6 was constantly measured with an electrostactic radon monitor belonging to the Max Planck Institute for Nuclear Physics of Heidelberg, Germany, in vicinity of the GERDA experiment. The radon monitor consists of a 700 liter tank kept at a pressure of 1.1 bar and flushed at 7 SLM. Alpha particles of the ^{222}Ra chain, being ^{218}Po and ^{214}Po, are detected by a silicon PIN diode located on the top of the chamber. The ^{222}Ra daughters are in an ionized state at production, and are drifted towards the diode by an electric field applied between this and the tank walls.
- The radon monitor has a total efficiency of $\sim$30%, an internal background of $\sim$0.3 mBq/m^3 and a sensitivity of $\sim$5 mBq/m^3 for a 15 min integration time.
- The detection efficiencies of ^{218}Po and ^{214}Po strongly depend on humidity due to the possible neutralization in presence of water molecules. Therefore a strong effort was done for keeping the humidity in CR6 as low as possible during its entire operation. A full characterization of the radon monitor response is foreseen for the next months.
- A LabVIEW VI was developed to monitor the radon level over time and automatically send alarms to the CUORE Alarm Server if the radon reached a pre-defined threshold.

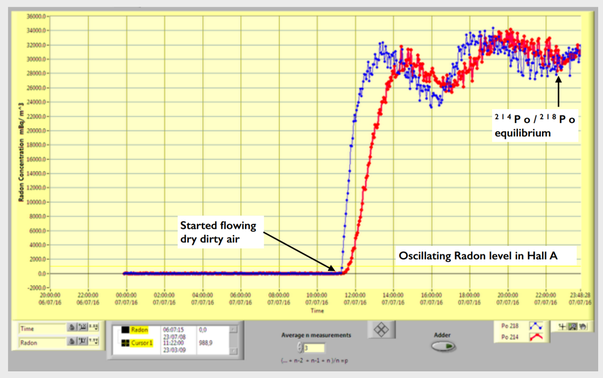


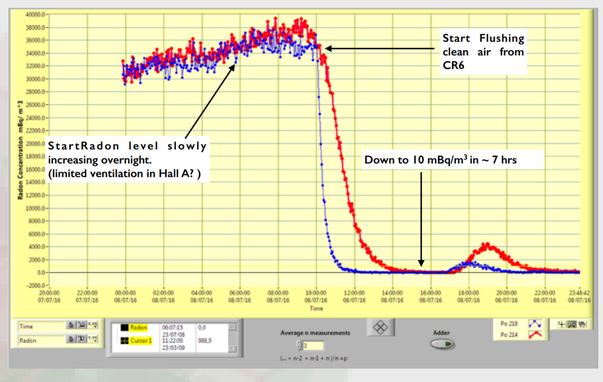




Performance of the Radon System

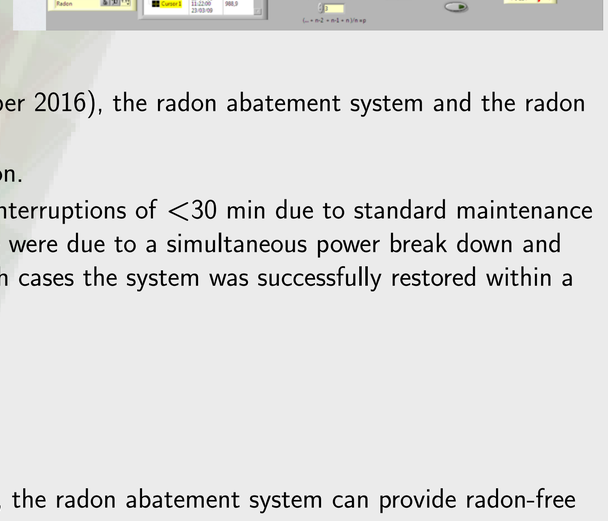
- Prior to the installation of the detector towers in CUORE, a characterization of the radon abatement system and of the radon monitor was performed. After flushing CR6 with radon-free air for two days and pumping air from it into the radon monitor, the air with $<5\%$ relative humidity exiting the dryer was measured for about one day. Within a couple of hours the ^{218}Po content went up to 30 Bq/m^3. About 6 hours later ^{218}Po and ^{214}Pb were in equilibrium. This measurement indicated that the efficiencies, previously measured by the radon monitor developer, were reliable and could be exploited for the measurement of CR6 air.
- Successively, the air from CR6 was measured after it had been flushed from the radon abatement system for several days. The radon level went down to $\sim$10 mBq/m^3 within about 7 hours, which corresponds to the recovery time of the entire system after a possible failure.
- In order to further prevent any exposure of the crystals to radon in case of unexpected interruption of the radon-free air flux into CR6, a nitrogen flushed bag was mounted around the towers during all the time in which no operation was performed on the detector assembly.

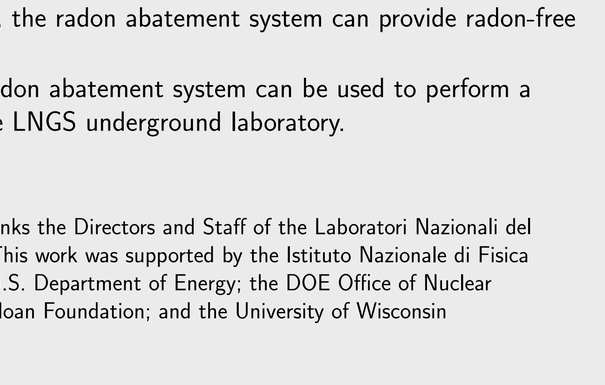




Procedures for the CUORE Tower Installation

- The entrance of CR6 consisted of a vestibule whose aim was to further separate the radon-free enviromnent dedicated to the detector handling from the rest of the world. A set of tests were performed before the start of the towers installation in order to determine the safe procedures for the access of CR6. The most important measure regarded the minimum time necessary between the entrance in the vestibule and the transfer to CR6 in order not to induce a radon-level increase up to more than a safe threshold, defined as 100 mBq/m^3.
- The response time of the radon monitor was measured with the simultaneous opening of the vestibule and CR6 doors, resulting in 7 min. With a waiting time in the vestibule of $\geq$10 min, the radon level was staying below the required level.
- Additional tests were performed, including the simulation of a system break down and the subsequent restart, with the goal of defining the response time required to the people in charge.
- At least two trained people were available 24/7 during the installation period.





Performance During Installation

- During the entire installation period (July-October 2016), the radon abatement system and the radon monitor were operated continuosly.
- The radon monitor was subject to no interruption.
- The radon abatement system was subject to 4 interruptions of $<$30 min due to standard maintenance operations, and to 2 longer interruptions. These were due to a simultaneous power break down and UPS failure, and to a compressor failure. In both cases the system was successfully restored within a few hours.

Outlook

- After the completion of the CUORE installation, the radon abatement system can provide radon-free air to other experiments at LNGS.
- Additionally, the dry air from the dryer of the radon abatement system can be used to perform a long-term measurement of the radon level in the LNGS underground laboratory.

Acknowledgments: The CUORE Collaboration thanks the Directors and Staff of the Laboratori Nazionali del Gran Sasso and the technical staffs of our Laboratories. This work was supported by the Istituto Nazionale di Fisica Nucleare (INFN); the Director, Office of Science, of the U.S. Department of Energy; the DOE Office of Nuclear Physics; the National Science Foundation; the Alfred P. Sloan Foundation; and the University of Wisconsin Foundation.